Data Assimilation and Model Simulations in the California Current

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LONG-TERM GOALS

The long-term goal of my research is to develop, verify, and apply numerical ocean prediction models to eastern boundary coastal regions in order to improve our scientific understanding of the structure and dynamics of such regions.

OBJECTIVES

The broad objective of this research is to aid in the development of a reliable modeling capability for eastern boundary current regions. The specific objectives are (1) to carry out and extensively verify several numerical model simulations of the annual cycle in the California Current, and (2) to evaluate and apply digital filter initialization (DFI) as a diagnostic tool in numerical ocean prediction.

APPROACH

The numerical simulations of the California Current are being carried out using the DieCAST regional model (Dietrich 1997). The DieCAST model is a z-level primitive equation model that uses a fully conservative fourth order space finite difference scheme on a pair of staggered and co-located computational grids (Dietrich 1997). As a result, the model has high computational accuracy and especially low numerical dispersion (Sanderson 1998; Sanderson and Brassington 1998). Both of these properties are essential for an accurate simulation of fine scale processes in the coastal ocean and at the shelf break. The model simulations are being verified using ONR's extensive eastern boundary current (EBC) data sets. Finally, I intend to evaluate digital filter initialization (DFI) as a diagnostic tool for ocean analysis, and to apply the method to several quasi-synoptic hydrographic data sets from the California Current and the Alboran Sea.

WORK COMPLETED

During FY98 and FY99, the high-resolution DieCAST coastal ocean model, with improved physics, was used to simulate the annual cycle of mesoscale variability in the California coastal region. Model improvements include reduced numerical dispersion, an annual cycle of climatological wind stress forcing (enhanced in magnitude near the coastal headlands), and barotropic and baroclinic boundary inflows and outflows. A six-year simulation produced results in general agreement with recent observations in the California Current. Some of the results from this simulation forced by climatological conditions were presented at the IUGG99 (Haney et al. 1999), and some were published in a multi-authored article in *EOS* (Miller et al. 1999). In our diagnostic studies using digital filter

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initialization (DFI), we validated the DFI method and used it to better understand mesoscale features in the California Current (Haney and Hale 1999, Shearman et al. 1999). Finally, we completed a study of the momentum balance in a strongly vertically sheared jet in the Alboran Sea (Viudez et al. 1999).

RESULTS

Using climatological forcing, our DieCAST model simulation reproduces many of the main features of the observed annual cycle of the California Current including the strengthening of the coastal jet in spring and the weakening of the jet in autumn and winter. Coastal eddies in the simulation form primarily off the major headlands, especially Cape Mendocino and Point Arena. As a result, a region of maximum eddy kinetic energy (EKE), originally formed in the upper ocean over the continental slope in late spring, migrates westward on a seasonal time scale. At the same time, the EKE spreads vertically into the deep ocean, decreasing the EKE west of about 126W. This result for the first time identifies a non-dissipative process that could account for the pronounced decrease of surface EKE west of 126W recently documented in the literature (Kelly et al. 1998, Strub and James 1998). Deficiencies in the model simulation include some artificial influences from the incompletely open western boundary, a somewhat exaggerated response of the surface circulation to the Mendocino escarpment, and the absence of a significant poleward surface current along the coast in winter.

In our diagnostic studies, we showed that the optimal form of DFI is able to diagnose accurately the 3-dimensional circulation and vertical velocity in an idealized growing baroclinic frontal wave. Most importantly, we showed that accurate measurements of the ocean currents, including the rotational part of the ageostrophic currents, are needed in order to diagnose the mesoscale circulation with DFI when the space scales are comparable to the Rossby radius. Having tested DFI, we then applied the method to synoptic hydrographic data collected during the CTZ program in the summer of 1988. The results indicated the existence of a prominent filament in the CTZ domain with maximum currents of the order of 0.6 ms^{-1}. This is somewhat stronger than surface geostrophic currents referenced to 700m, thus demonstrating that the anticyclonically curved jet was supergeostrophic. The strongest vertical velocities, of order 10m/d at 100m, were associated with meanders in the otherwise straight jet. This type of meander-induced vertical motion is consistent with that expected from the conservation of potential vorticity, and it is similar to that found in Gulf Stream meanders (Bower and Rossby 1989; Lindstrom and Watts 1994). In a separate collaborative study using DFI, we studied a closed cyclonic eddy observed off Point Arena California. The eddy was diagnosed as having relatively small vertical velocities on the scale of the eddy itself, but to have very significant vertical velocities (w~30m/d at 100 m) associated with sub-eddy scale meanders in the otherwise circular flow around the eddy. Finally, our diagnostic study of the momentum balance in the Atlantic Jet in the Alboran Sea showed that vertical advection of momentum is negligible even when the vertical shear is very large, as is the case in the highly baroclinic Atlantic Jet.

IMPACT/APPLICATIONS

Our California Current annual cycle simulations are among the most advanced ones to date. Because of the excellent observational data sets being used, the model verifications will represent the standards against which other models will be evaluated in the future. The validation and use of DFI as a diagnostic tool in the ocean will have important impact in advancing diagnostic ocean studies and numerical ocean prediction.

TRANSITIONS

Our research on data assimilation and simulations in the California Current is in broad support of the efforts at FNMOC (M. Clancy) and NRL-Stennis (J. Kindle) to develop a real-time ocean analysis and forecasting capability, including biology, for this region. This support manifests itself in close coordination, and timely information exchange on such topics as model properties, experimental set-up, forcing data, regional modeling difficulties, comparison and exchange of results, methods of model verification, and so forth.

The DFI methodology has been accepted as the major diagnostic tool for estimating the ageostrophic circulation and vertical motion in the EC-sponsored OMEGA project. This multinational European project completed six quasi-synoptic oceanographic surveys in the western and central Mediterranean last year.

RELATED PROJECTS

I am collaborating with J. Barth (OSU) to apply the DFI diagnostic method to the EBC synoptic hydrographic data and with Julie Pullen and others at NRL-Monterey to validate the Navy's high resolution coastal ocean model (NCOM) in the Mediterranean Sea. I am also collaborating with J. Tintore (UIB, Spain) in diagnostic studies of mesoscale variability in the Alboran Sea (Gascard et al. 1999; Velez et al. 1999) and in modeling the interanual variability in the Mediterranean Sea. Finally, I am planning to participate in a National Ocean Partners Program (NOPP) to inter-compare ocean models and to synthesize observations off the West Coast of North America.

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